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ABSTRACT

Two experiments were conducted to determine the features of text to which skilled adult readers need to attend while reading and the features that either are of minimal importance or can be processed automatically without directed processing. In the first experiment, 12 college students attended to a timed picture naming task, in which a picture was presented to a subject for naming at the same time that a word was presented to the picture's right. The pictures were shown in each of five experimental conditions: (1) with no word, (2) with a series of letters that could not be construed as an English word, (3) with letters that were an approximation of an English word, (4) with a word that was not an associate, and (5) with a semantic associate word. In the second experiment, 14 college students were asked to determine whether a series of letters was in fact an English word. Accompanying each series of letters was an unattended stimulus word. The two experiments showed that for skilled readers the meanings of words are recognized automatically, and that the grapheme-to-phoneme correspondence rules also operate automatically. (FL)

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ATTENTION AND WORD RECOGNITION IN SKILLED READING

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INTRODUCTION

Reading is a selective process. As a page is inspected the reader must select the words and phrases in a particular order, he must select the interpretations of the words which he thinks were intended by the writer, and he must combine the meanings of the words in a unique way to come to understanding of the meaning of the passage. These are selective processes in that alternatives may be considered and rejected before the appropriate choice is made. When choice is available attention is necessary, and the purpose of this discussion is to determine those components of the reading process which require attention, and those which can proceed automatically. Laberge and Samuels (1974) emphasized that fluent reading is dependent upon automatic processes because we have a limited capacity for conscious, attentional processing, and suggest that the development of such automatic processing should receive greater emphasis in reading instruction. To this end, practice on a subskill of reading should continue until automaticity has been reached. Only when lower level subskills (e.g. letter recognition, word pronounciation, word meaning recognition) are fully automatic will enough attentional capacity be available for the beginning reader to progress to the next developmental level. The experiments presented here attempt to determine some of the subskills which are automatic in adult skilled readers - if we know how adult readers behave when confronted with print then perhaps we can learn what children attempt to do and what we should be helping them to do.

The experiments and their analyses will be presented within a popular framework used by cognitive psychologists - the identification of component processes which are applied to the information available in the environment. This framework assumes that the environment contains information which is processed through the senses in a series of stages, or transformations, until it reaches the state required by the individual. At this point a response may be prepared, and this may be an overt response (e.g. reading a word aloud) or it may be covert (e.g. integrating a word with the story schema). Reading lends itself very well to this analytic framework, and the stages of information processing can be seen to include such transformations as extraction of the critical visual features of the printed lines on the page, assignment of meaning to those features by contact with memory, conversion of the visual (or graphemic) form of a word to the phonological form as a possible preparation for vocal output, and the combination of word meanings into abstract ideas. More complete descriptions of this "information processing" analysis can be found in Underwood (1978), and it is specifically applied to the

reading process by Underwood and Holt (1979).

When a printed word is read aloud it undergoes a series of transformations from being a set of marks on a page to becoming a spoken utterance. Each transformation requires a cognitive proess to be applied to the previous state of the coded information. The concern of the following experiments is with the question of how much of this processing of print into meaning can become skilled and automatic, and how much demands attention in the skilled adult reader.

Clearly, reading of a kind can be performed without attention. Most of us are familiar with the experience of having our eyes arrive at the bottom of a page of a book with the realisation that we have looked at the words and recognised many of them, but that the underlying meaning of the passage has eluded us. Usually we have been thinking about something other than the passage which we thought we were reading - our attention was elsewhere and yet we were able to perform some of the subskills of reading. Solomans and Stein (1896) were among the first to investigate this phenomenon of "automatic reading", and with practice became sufficiently skilled to read at the same time as performing other tasks. The "automatic reader", upon returning his eyes to the top of the page, may have a feeling of familiarity with the text, and this indicates that words were processed to some extent during the first "reading" of the page. Many novels can be read in this way without loss of meaning, and children's stories can be read aloud by the practiced parent who does not need to attend to what he is reading. Intonation can be added and a convincing demonstration given of enjoyment, but with no comprehension of what is read on the part of the reader. The position to be presented here is that invariant subskills such as word identification may be performed without attention, but that processes which demand attention are those which require the selective integration of word meanings. In both of the following experiments the reader's attention was captured by a timed task, and the effect of an unattended word upon the attended task was observed. If the meaning of an unattended word can affect an attended task, then we may infer that the word has been read automatically and that attention is not required for the analysis of individual word meanings.

EXPERIMENT 1

This experiment determines whether the meanings of individual words are processed even when the words are not being attended. The subjects attended to a picture-naming task, and their responses to this task were timed. At the same time as presenting a picture for naming, a word was presented to the right of the picture. The nearest point of the word was one and a half degrees of visual angle from the point of fixation upon the picture, as mesured from the viewing position of the subject. Full details of the display, and of the experimental procedure can be found in Underwood (1976), and so only the essential features will be described here.

Twelve different pictures were used, and they were simple line drawings of a bird, a boat, a car, a cat, a chair, a duck, a fish, a flag, a house, a lemon, a pan, and a train. Each picture was presented in each of five experimental conditions, and these depended upon the relationship between the picture and the unattended word presented at the same time. These five conditions were as follows. In Condition 1 each picture was presented alone, with no word accompanying it. In Condition 2 the picture was accompanied by a meaningless string of letters which could not be an English word. These letter-strings were zero order of approximations to English (e.g. the letter-string ETZCI). In Condition 3 the picture was accompanied by a letter-string which was a fourth order of approximation to English. These letter strings are not words, but are orthographically legal and can be pronounced (e.g. ERINCHE). In Condition 4 the picture was presented with a word which was not an associate. For example, with the picture of the chair, the word was "press". In Condition 5, a word accompanied the picture, and the two were semantic associates, e.g. the picture of the cat and the word "cream". Words and non-word letter-strings were matched for length across the five experimental conditions. Words were matched for frequency of occurrence in written language. All words were printed with upper case letters.

Pictures and words were presented through a tachistoscope (Scientific Prototype model GB) for an exposure duration of 60 milliseconds. The subjects task was to name the picture as quickly as possible without making any errors. The vocal response to the picture operated a voice switch which in turn stopped a timer which had been started at the same moment as exposure of the picture and word. Subjects were instructed to concentrate on the picture and ignore anything else which they might see. They were not asked about the words until after the experiment.

Twelve skilled readers were used in the experiment, all of them were undergraduates at the University of Waterloo, Canada. Subjects were tested individually with all stimuli. A different randomised order of presentation of stimuli was used with each subject.

Results

Errors were recorded on less than 3% of trials, and when an error did occur, the trial was repeated later in the experiment. The response times for each of the experimental conditions are as follows.

Experimental Condition (Unattended Word)	Mean Picture Naming Latency
No Unattended Word	581 msec (s.d. 53 msec)
Zero Order Approximation To English	594 msec (s.d. 51 msec)
Fourth Order Approximation To English	591 msec (s.d. 55 msec)
Unrelated Word	593 msec (s.d. 59 msec)
Related Word	617 msec (s.d. 52 msec)

The standard deviations from each condition indicate homogeneity of variance, and so the twelve responses from each subject within each of the five experimental conditions were submitted to an analysis of variance. Type of unattended stimulus was indicated to be a reliable source of variance ($F=9.1$; $df=4,44$; $P<0.001$), and so the five treatments were compared individually using a Newman-Keuls test. The only difference revealed by these comparisions was that the presence of a semantically related word slowed down the naming response to the picture over the other four treatments ($P<0.05$), and so there are no differences within these four treatments.

This experiment indicates that the meaning of an unattended word is processed for meaning. Attention is not necessary for the recognition of the meaning of individual words, otherwise a related word would not have slowed down the picture naming response in comparison with an unrelated word. For this critical difference to exist two processes are essential: the unattended word must be processed for meaning, and its meaning must interact with the meaning of the picture. The difference between related and unrelated words indicates that they had been read unconsciously, and that word meanings are

recognized without our needing to attend to them.

We can demonstrate that skilled readers do not need to attend to words in order to process their meanings by observing the effect of the meanings of unattended words upon an attended activity such as picture naming. The second experiment used this procedure to determine whether the phonological codes of words are generated automatically just as their meanings are recognised automatically.

EXPERIMENT 2

If words related to an attended stimulus affect the response latency to that stimulus, then what will be the effect of a word which is not related but which sounds as if it is related? Experiment 1 demonstrated that a word such as "sail" affects the latency of response to a picture of a boat, but what would be the effect of the word "sale" upon the response to the picture of a boat? These two words are heterographic homophones, and only if the common phonological form is accessed auomatically can they both affect the picture. Experiment 2 investigated the possibility that the phonological code is generated automatically by presenting unattended words which were homophones of related words. If the homophones of related words slow down the response to the attended stimulus, then we can infer that they are converted to the phonological code unconsciously.

This experiment could not use picture naming as the attended task because any task involving naming might interfere with the possible generation of the phonological code, and complicate the interpretation of the results. Accordingly, a task was used which did not involve naming, but which does involve the processing of meaning - the lexical decision task. This requires the reader to judge whether or not a letter string exists as a word, and to respond "yes" or "no" in response. So, when presented with the letter string "FISH" the response should be "yes", and when presented with "FITH" the response should be "no". In Experiment 2 the subjects were presented with a letter string to fixation, and they were required to make a lexical decision response to each one. Accompanying each letter string was an unattended stimulus. This unattended stimulus was presented to the right of fixation, about 2 degrees of visual angle away from the nearest letter of the attended letter string.

On half of the trials the attended stimulus was a word and on half the trials it was a nonword. Nonwords were fourth order approximations to English, and were therefore pronounceable. All nonwords were pseudohomophones (e.g. "BURD" and "BLOO"), in an attempt to discourage the subjects from using the phonological code

in the lexical decision task. Nonwords were matched with words for length. When the attended stimulus was a word, the accompanying unattended stimulus was a word on half the trials and a nonword on the other trials. When the unattended stimulus was a word, it fitted one of five experimental conditions. In Condition 1 the unattended word was unrelated to the attended word and was not a homophone (e.g. attended word "SMILE", unattended word "THING"). For comparison with Condition 1, Condition 2 presented unattended words which were related to the attended words but which again were nonhomophones (e.g. "THREE" accompanied by "FIVE"). In Condition 3 the unattended word was a homophone, and was unrelated to the attended word (e.g. "GREEN" with "BEAR"). In Condition 4 the unattended word was related to the attended word, and was a homophone (e.g. "CHOIR" presented with "HYMN"), and in Condition 5 the unattended word was not itself related to the attended word, but was a heterographic homophone of a related word (e.g. "RUBBISH" with "WAIST"). Full details of the stimuli used in this experiment, together with experimental procedures, can be found in Underwood and Thwaites (1982).

Sixty words were presented to fixation, and sixty nonwords. With thirty of the words the unattended stimulus was a word, and each of the five critical experimental conditions contained six words. Stimuli were presented in upper case letters on positive slides, projected using a tachistoscopic slide projector (Forth Instruments). To ensure that subjects did not see the unattended words a masking stimulus was used over the location of the unattended words and this visual noise stimulus was projected at all times except when the experimental stimuli were projected. Stimuli were projected for an exposure duration of 50 milliseconds. Subjects sat facing the projection screen with one finger on a button marked "word" and another finger on a button marked "nonword", and were instructed to press the appropriate button as quickly as possible when the stimulus was presented. They were instructed to concentrate on the letter string to which the lexical decision response was to be made, and to ignore anything else which they might see. Presentation of a slide started a timer which was stopped by depression of either response button.

Fourteen subjects took part in this experiment, and all were undergraduate students at the University of Nottingham. They were all tested individually on all of the stimuli, and a different random order of stimuli was used for each subject.

Results

The latencies from the trials in which nonwords were presented are not of interest to this discussion, and so

will not be presented here. Full details can be found in Underwood and Thwaites (1982). The response latencies from the conditions in which an attended word was accompanied by an unattended word are as follows.

Experimental Condition (Unattended Word)	Mean Response Latency to Attended Word (Lexical Decision)
Nonhomophonic Unrelated Word (SMILE ¦ THING)	542 msec (s.d. 64 msec)
Nonhomophonic Related Word (THREE ¦ FIVE)	577 msec (s.d. 76 msec)
Homophonic Unrelated Word (GREEN ¦ BEAR)	551 msec (s.d. 60 msec)
Homophonic Related Word (CHOIR ¦ HYMN)	576 msec (s.d. 68 msec)
Homophone of a Related Word (RUBBISH ¦ WAIST)	596 msec (s.d. 79 msec)

Analysis of the five critical conditions with an analysis of variance indicated that the unattended word was a source of variation ($F=5.36$; $df=4,52$; $P<0.001$), and planned comparisons were used to compare individual pairs of conditions. When the unattended word was a related nonhomophonic word, then the response was slower then when the nonhomophone was unrelated ($P<0.01$). When the unattended word was a homophone which was related to the attended word it slowed down the response to the attended word in comparison with the effect of an unrelated homophone ($P<0.05$), and when the unattended word was a heterographic homophone of a related word the response was slower then when it was an unrelated homophone ($P<0.005$).

This experiment confirms the effect found in Experiment 1, in that the meaning of an unattended word is shown to affect the processing of an attended stimulus if the two are related in meaning. Furthermore, the effect can be observed if the unattended word is not related in meaning but <u>sounds</u> as if it is. We must infer from this result that (i) the meaning of an individual word is recognised automatically, and that (ii) the phonological code of a printed word is generated automatically. Attention is not required for the recognition of meaning or for the conversion of a printed word into the code which is necessary for articulation. Not only can we read meanings unconsciously, but we prepare for articulation unconsciously too. In both of these experiments subjects were asked, after the experiment, what they had seen of

the unattended words. Subjects sometimes reported that they had seen a stimulus to the side of the screen, but could never report any of the words, and usually were unaware that words had been presented at all. These introspective comments support the notion that words can be recognised unconsciously.

DISCUSSION

These experiments demonstrate that for skilled readers the meanings of words are recognised automatically, and that the grapheme-to-phoneme correspondence rules (GPC rules) also operate automatically. When the skilled reader looks at a word, its meaning becomes available without the reader having to search for it with conscious effort, and a program for its articulation also becomes available. Not every word is required in its articulated form when reading, of course, and the processing of the phonological form of the word stops short of the production of speech. These results are restricted to the case of individual words, and while it is clear that words may be recognised for meaning without the reader being aware of them, it is not clear what processes must be applied to combinations of words in phrases and sentences in order to gain an appreciation of the underlying meaning. Demonstrations are available of the effectiveness of words printed to the right of fixation (i.e. where the next fixation might occur in natural reading), but demonstrations are not as plentiful for the case of reading sentences as they are for the case of the reading of individual words.

Two experimental paradigms have been used to investigate the question of the influence of unattended words during natural reading, and both provide evidence to suggest that these words do affect performance. Neisser (1969) and Willows and MacKinnon (1973) observed the effect of words printed between lines of text, and McConkie and Rayner (1975) and Kennedy (1978) monitored eye movements to observe the effects of non-fixated text upon current fixation behaviour.

One particularly fascinating result to come out of this research concerns the relationship between reading ability and the processing of unattended words. Willows (1974) tested groups of 11 year old good and poor readers on a task which required them to read aloud a passage which had unattended words printed between the to-be-read lines. As expected, the good readers completed the oral reading of the passages faster than the poor readers, and produced fewer comprehension errors on the multi-choice questions at the end of each passage when given passages with no unattended lines. However, when they were given the experimental passages, the good

readers often selected alternatives in answer to the comprehension questions in the form of words which had appeared between the lines. Thus, one passage contained the sentence "inside were long counters on which things collected by the children were displayed" and one of the comprehension questions was "on what were the things displayed?". Among the six alternative answers was "folding tables", and these words had appeared several times printed between the lines of text to be read aloud. Selection of "folding tables" constituted an intrusion error, and it was the good readers who made more intrusion errors than the poor readers, suggesting that they had accepted more information from the unattended lines than did the poor readers. This is an important result, and suggests that one characteristic of good reading habits is to not focus narrowly upon that which is being fixated, and to accept information from a greater area of the page.

Willows' (1974) study of the effects of nonfixated words upon reading behaviour is consistent with the studies of the effects of unattended words in the tachistoscope experiments presented in this discussion, and together they go some way to suggesting that the skilled reader does not restrict his input to that which is fixated. Words ahead of fixation may be use in determining the location of the next fixation (see Underwood, 1981, for a fuller discussion of this issue), and attention may be captured by the processing of "interesting" unattended words. Interest is defined here as anything which is related to the schema of the text, or even to the meaning of the words currently being fixated.

We can "read" to the bottom of a page of text and fail to understand its meaning whilst at the same time have a feeling of having seen each of the words. Automatic processes can take care of word recognition but they cannot take care of the integration of word meanings. The skilled reader attends to the relationships between words, rather than to the individual words themselves, but when distracted from the task of discovering the underlying meaning of a passage he can still pass his eyes over the page and recognise much of the text. Unconscious reading of a page is the recognition of individual words whilst thinking about other ideas, but to understand the passage it is necessary to attend to the relationships between the individual words. Word integration is an active, non-automatised process in that it requires attention. It must be an attended and selective process because choice is involved, and alternatives created as well as selected between. The hypothesis-testing models which suggest that the reader samples the print to confirm or disconfirm his expectancies (e.g. Hochberg, 1970; Levin and Kaplan, 1970), must also require the reader to generate and modify these hypotheses whilst information is being extracted from the text.

These are processes which resemble thinking, as Neisser (1967) suggested, and are processes which require attention. They cannot become automatised because a unique combination of word integration is necessary upon reading each sentence. Word recognition may become automatic because words, by their very nature, have meanings which do not change substantially over time. Their meanings are regularly qualified by their context, of course, and this is the very process of word integration for which attention is essential. Individual words may be recognised while attention is elsewhere, and while they are being recognised automatically, attention should be directed towards the combination of their meanings in a process which closely resembles thinking.

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